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and the Description of an Allied Form

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## A Study of the Salamander *Plethodon ouachitae* and the Description of an Allied Form

Clifford H. Pope\* and Sarah H. Pope

Although *Plethodon ouachitae* was described in 1933, its status has remained uncertain, and almost nothing has been added to the original account. Deploing this situation we went to Arkansas to observe the species in the field, a procedure highly advantageous in a study of animals that lose many of their color characters soon after preservation. The recent study of a close ally, *P. yonablossee* (Pope, 1950), impressed us with the necessity of a similar statistical and ecological treatment of *ouachitae*. All of this work on salamanders aims at an investigation of speciation in the group of large *Plethodons* of the eastern United States (Grobman, 1944, p. 266).

### MATERIAL AND METHODS

This paper is based primarily on a field investigation made in Arkansas on Rich Mountain and in the Caddo Mountains (Fig. 1). A large series of *Plethodon ouachitae* was preserved for statistical study, and, in addition, many specimens were observed but not preserved. The three salamanders collected in the Caddo Mountains appear to represent a new form.

We have gone through the literature and made use of material in our institution (CNHM) as well as that in the museums listed below. We here thank these institutions together with the herpetologists in charge. Parentheses enclose the initials hereinafter used in referring to the museums.

Museum of Comparative Zoology, Arthur Loveridge  
American Museum of Natural History, Charles M. Bogert  
United States National Museum (USNM), Dr. Doris M. Cochran  
Museum of Zoology, University of Michigan (MZUM), Dr. Norman Hartweg  
Carnegie Museum (CM), Dr. Grace L. Orton  
Cincinnati Museum of Natural History (CMNH), Ralph Dury

While working on Rich Mountain we made headquarters at the home of A. J. Gorges of Eagleton, and to him we express deep appreciation for

\*Chicago Natural History Museum, Chicago 5, Illinois.

friendly assistance that furthered our work as well as added to our pleasure and comfort.

Collecting was random and took place in daylight. After being killed with chlorethane, the specimens were stretched out in formalin to harden for an hour or two, then injected with and submerged in it. Within a month all were permanently stored in alcohol.

The anterior angle of the vent was used in making the snout-vent measurements with Vernier calipers. Tail length was obtained by subtracting this snout-vent dimension from the total length, which was made by stretching the specimens along a ruler. Measurements were first taken to the nearest 0.5 mm. but those with this fractional value were finally raised to the next whole number. Every arithmetic mean is accompanied by its standard error. All measurements were made weeks after preservation.

Fifty-foot-interval contour maps of the United States Geological Survey, a small aneroid barometer, and local bench marks were used in calculating altitudes.

### DISTRIBUTION

*History.* *Plethodon ouachitae* was described by Dunn and Heinze in 1933 from two widely separated places on the northern flank of Rich Mountain (Fig. 2): "east of Page," and "near the junction of a road to the top, and a road leading to an observation tower." The first place is in southeastern Le Flore County, Oklahoma, near the Arkansas line, and must be southeast rather than east of Page, whereas the second, designated as the type locality, is in northwestern Polk County, Arkansas, near the road junction (Rich Mountain Settlement Road with the Skyline Drive) 2.2 miles northwest of the fire lookout or "observation tower," which itself is **SSE** of Rich Mountain Settlement and on the highest point attained by Rich Mountain in Arkansas. These two places are about nine miles apart.

Two years later (Burt, 1935, p. 312) reported a specimen from "6 miles northwest of the settlement of Rich Mountain." His doubt as to the correctness of his identification is of little importance since he certainly took his specimen on Rich Mountain at a point between the places where the type series was collected. A scrutiny of maps of the region will convince anyone

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Figure 1. Polk and Montgomery counties, Arkansas, with adjacent regions, showing Rich Mountain, the Caddo Mountains, and the Novaculite Uplift. The two collecting sites of *Plethodon caddoensis* (Polk Creek Mountain, which is the type locality, and Caddo Gap) are indicated by X's.

The inset map shows how the area of the larger map lies almost entirely within the Interior Highlands.

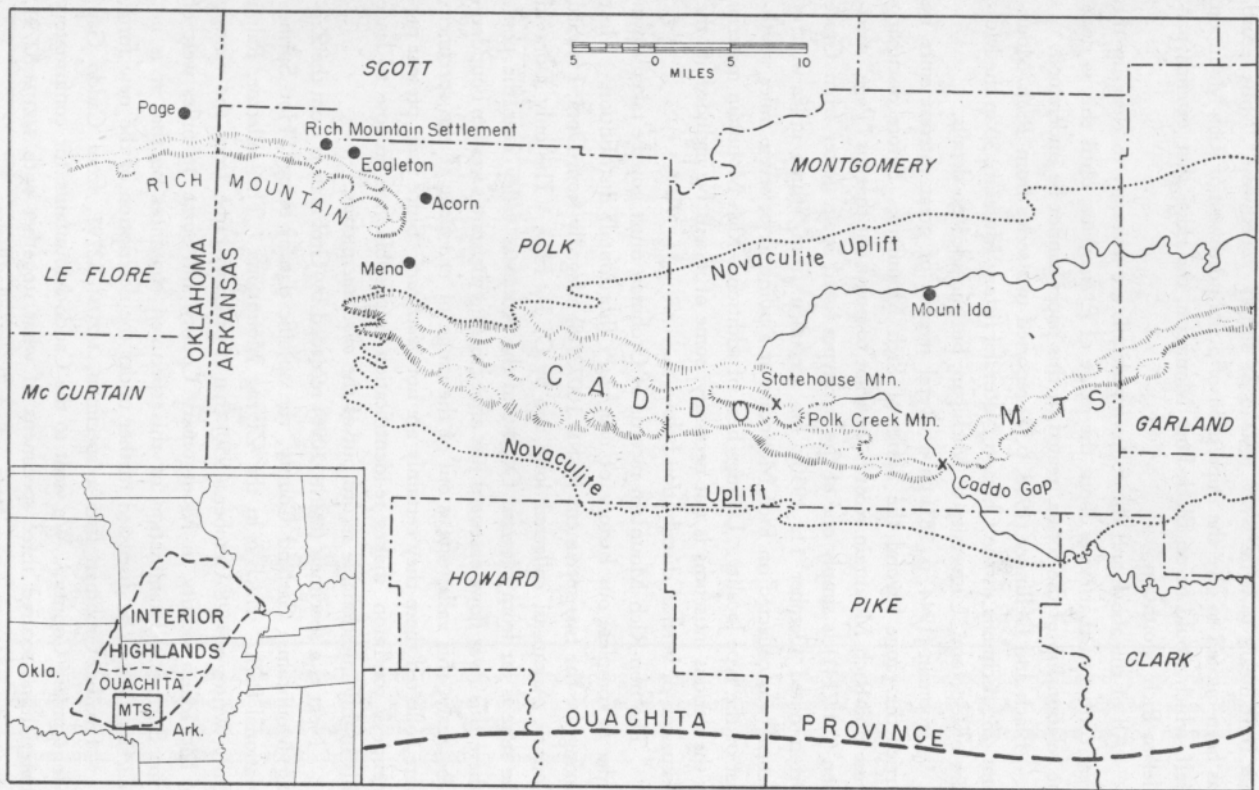


Figure 1

that Burt meant to write WNW instead of simply "northwest." His record has been quoted to give the impression of a site northwest of Rich Mountain itself, which would be on Black Fork Mountain, the ridge that extends parallel to Rich Mountain.

All of the above and the following details are necessary to clear up the great confusion that exists about the range of *P. ouachitae*; until this is done the relationship of the forms treated in this paper cannot be understood.

Black and Dellinger (1938, p. 8) reported two series from Rich Mountain: 26 specimens in the Chicago Natural History Museum, 30 in the Museum of Zoology, University of Michigan, but included no details.

Grobman (1944, p. 285) gave several records of great interest since he carried the range beyond the limits of Rich Mountain. Before discussing these non-Rich Mountain records we want to point out that his "Page" specimen (CM 7141) is simply one of the paratypes listed again (letter from Grace Orton dated October 11, 1950); his specimen from "three miles west of Acorn" was collected on Rich Mountain at a point six or seven miles southeast of the type locality. Listings here of additional Rich Mountain material in the various museums is not necessary; some of it will be included in the discussion of vertical distribution below.

The non-Rich Mountain records of Grobman must now be taken up in order to complete our history of *ouachitae*'s (horizontal) distribution. Most vexing are the two specimens (USNM 100777-8) allegedly from Dora, Howard County, Arkansas, collected long ago by O. P. Hay. The only Dora in the state is far from Howard County in the Arkansas valley near the point where this river flows eastward just after crossing the state's western boundary. Obviously, this valley site is out of the range of *ouachitae*; if the specimens were collected there they certainly are not *ouachitae*. Since their present pigmentless condition makes re-identification impossible, we propose to leave this highly questionable record out of the *ouachitae* picture.

Next is a specimen (CMNH 2096) recorded by Grobman as from the Zigzag Mountains, Garland County, the specific datum being "Hot Springs National Park," which is in the Zigzag Mountains. The collector, Ralph Dury, writes me (28 October, 1950) that it probably came from the vicinity of Mt. Ida, a locality in Montgomery County and some 36 miles west of Hot Springs. Examination of this specimen convinces us that it is not *ouachitae*; it will be discussed further under the description of the new form.

Finally, Grobman lists a specimen, MZUM 82791, from Caddo Gap, Montgomery County. We went to the Caddo Mountains for confirmatory material and secured three specimens of what, together with MZUM 82791, appears to represent a new form, which is described below.

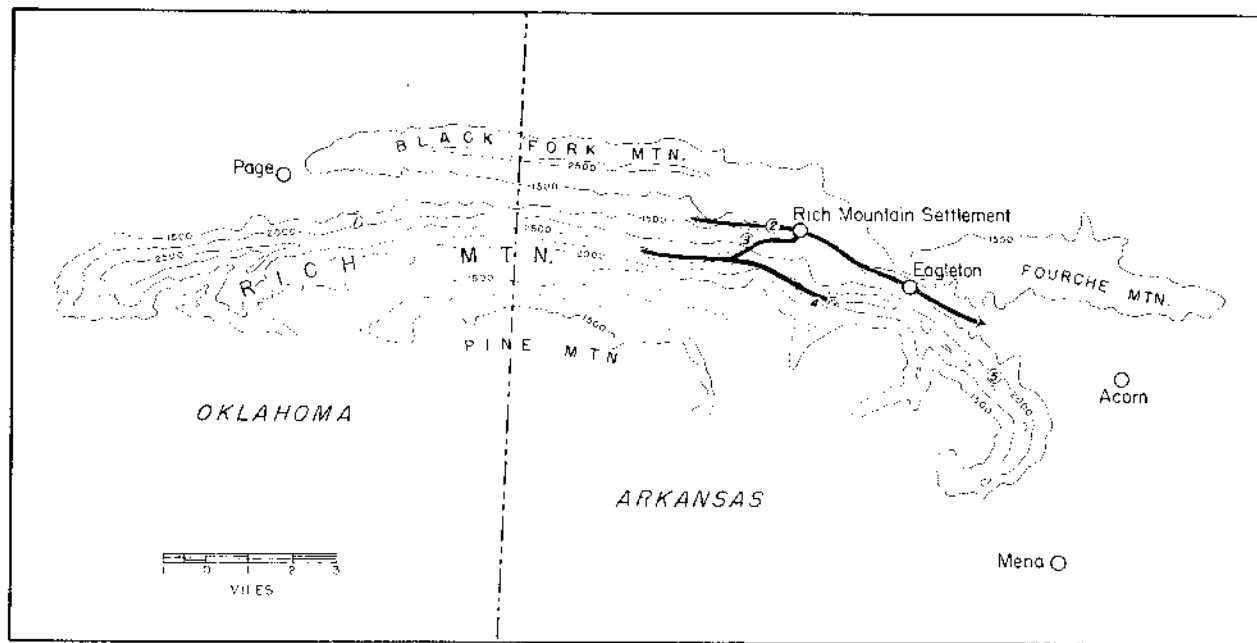


Figure 2. Map of Rich Mountain with the important collecting sites of *Plethodon ouachitae* indicated as follows: "East of Page," approximately allocated by the numeral 1. Half a mile west of Rich Mountain Settlement, indicated by the numeral 2. Two adjacent sites along the Rich Mountain Road, shown by the numeral 3 (the actual type locality is included here). Fire lookout site, shown by the numeral 4. Three miles west of Acorn, approximately allocated by the numeral 5.

The specimen (Dundee 1583) recorded by Dundee (1947, p. 117) from the floodplain of Mountain Fork River at a point 8 miles east of Broken Bow, McCurtain County, Oklahoma, has been examined by us. It, a female, apparently represents an undescribed form that differs from *ouachitae* in several characters, the most important of which are:

The invasion of the belly laterally along its entire extent by the dense white pigment of the sides. Even the midline region exhibits considerable light pigment.

A throat more conspicuously mottled and with more contrast between light and dark elements than in *ouachitae*, with few possible exceptions.

The ventral aspect of the upper legs is light with mere traces of dark pigment, a condition never seen in *ouachitae*.

The low vomerine tooth count, 7 teeth on the right, 6 on the left. Even if allowance be made for an error of one tooth on a side, this count is extremely low for adult *ouachitae*. The specimen measures 64 mm. from snout to vent and has a regenerated tail.

The original coloration of Dundee's specimen is unknown but one would assume that certain conspicuous elements have been lost. Because of this a full description is not given here. The lowland habitat of this striking animal is in strong contrast to that of *ouachitae*.

This disposes of all records of *ouachitae*, and compels us to conclude that: (1) *P. ouachitae* is as yet known only from Rich Mountain; (2) at least two other closely allied and undescribed forms occur in the surrounding territory.

*Vertical Distribution.* Rich Mountain extends east and west for approximately 20 miles before curving southeastward to end in a hook near Mena. Its crest maintains an altitude of 2500 feet or a little more throughout most of the east-west extent, reaching an elevation of 2850 feet at two widely separated points, one in Oklahoma, the other in Arkansas. It is flanked on the north and south by somewhat lower mountains separated from it by valley floors largely above the 1250-foot level. All this results in a mountainous terrain of considerable extent and elevation.

*P. ouachitae* occurs from the crest of the highest part of the ridge in Arkansas (2825 feet) to 1700 feet on the northern flank of the mountain (0.5 miles west of Rich Mountain Settlement) where the valley floor itself has an altitude of about 1600 feet. In short, it occupies the northern flank of the mountain from its crest to the edge of the valley floor. We found it abundant at 2825 feet and common at 1950 to 2150 feet. We did not do enough work at the lower levels to secure many data on its incidence there,

but confirmation of its presence at low levels is found in Burt's (1935, p. 312) record for the base of the mountain, a small series, MZUM 77381-2, from 1800 and 1900 feet, and two specimens, CNHM 28408-9, from about 1800 feet. All of these are also from the northern flank.

*General Considerations.* A study of the local geography and geology as described by Fenneman (1938, p. 663-689) reveals certain facts pertinent to salamander distribution. The Ouachita Mountains are the southernmost subdivision of the Interior Highlands. This subdivision is surrounded on the east and south by low plains, and on the west by the dry, slightly elevated Central Lowlands. On the north, the low Arkansas valley separates the Ouachita Mountains from the mountainous Ozark region. This significant degree of isolation coupled with great geological age and a forested mountainous terrain, the result of extensive folding of Palaeozoic strata, produces conditions ideal for speciation in a group of animals such as the large Plethodons. Moreover, extensive speciation of the group has taken place in the Appalachian Highlands, part of which may in fact be a continuation of the Ouachitas.

Rich Mountain, a monoclinical ridge, itself might be called the culmination of the Ouachitas because summits as well as valley levels decline in all directions from it, the ridge actually lying near the axis of uplift. The Jack-fork sandstone exposed at the surface of Rich Mountain is of Carboniferous age. To the southeast extends a subdivision, the Novaculite Uplift, where the Carboniferous rocks have eroded away, leaving the Devonian novaculite exposed. The Caddo Mountains, where the new form was taken, lies in this area. Mt. Ida is also in the Novaculite Uplift but on the opposite side of the Crystal Mountains (highest point 1834 feet) from the Caddo Mountains. The Crystal Mountains are the only range in the Novaculite Uplift area not formed of novaculite or the associated Hot Springs sandstone. Thus it is evident that *P. ouachitae* and the new form inhabit areas with different geological histories.

#### ECOLOGY

*Incidence.* *P. ouachitae* is anything but rare on Rich Mountain as the following facts show. Counting only the six days on which *ouachitae* was seen, we secured in woods (where conditions had not been disturbed recently) 65 specimens in 21 man-hours of actual work. One of us, working under optimum conditions, was able to take this species at the rate of 6.5 specimens per hour on one occasion, 10 an hour on another. During four man-hours of work we captured 131 individuals near the fire lookout as described in the

discussion of habits. Since this was definitely a disturbed site, no such catch would likely be made in the undisturbed woods.

*Association.* The only closely allied *Plethodon* found on Rich Mountain is the ubiquitous *P. glutinosus glutinosus*. The two species live in close association but *ouachitae* is the more abundant as shown by the following tabulation of seven catches in three sites: 18 to 1; 14 to 3; 13 to 2; 11 to 6; 5 to 0; 3 to 2; 1 to 0. These data add up to 65 *ouachitae* and 14 *glutinosus*, or about five to one. Oddly enough, not a single *glutinosus* was seen in the disturbed fire lookout area where 131 *ouachitae* were captured in one morning. In fact, the only other salamander seen at this productive site was a specimen of *Plethodon cinereus serratus*.

The association between *glutinosus* and *ouachitae* was so close that a difference in habitat was not detected: on one occasion, two individuals were taken but six inches apart in a single hideout.

*Habitat.* Rich Mountain is covered with continuous, dense, second-growth, mixed-deciduous forests that are stunted and ragged along the crest of the ridge. Apparently, this raggedness is made by ice storms. In many places the steep slopes are covered with fragmented Jackfork sandstone, the fragments being of various sizes and covering the ground in places to considerable depth. When well covered by the forest and its debris, these talus slopes form ideal retreats for woodland salamanders and, incidentally, make collecting very difficult.

We secured *ouachitae* at four sites, all on Rich Mountain and in Polk County: (1) At 1700 feet on the edge of the valley floor 0.5 miles west of Rich Mountain Settlement on the west-facing slope of a small foothill, in mixed-deciduous woods with some small pine trees, and sparse ground cover over a stony substratum. One specimen was collected April 19. (2) At 1950-2150 feet above and below a point on the Rich Mountain Road 0.7 miles below its junction with the Skyline Drive, in dense, mixed-deciduous forests of a steep talus-strewn, northwest-facing slope with many logs and thick ground cover. Fifty-nine specimens were collected April 30, May 1, 2, 3, and 5. (3) At 2250 feet just below the junction of Rich Mountain Road with the Skyline Drive on a steep, northwest-facing slope, in woods essentially like those of the preceding site. This is literally the type locality, and five specimens were secured on May 1. (4) At 2825 feet about 200 yards southwest of the fire lookout, in thin, deciduous, chiefly oak woods of the relatively level crest. This was a disturbed site as explained in the discussion of habits below. One hundred thirty-one specimens were secured on May 6 but only 60 of them were preserved.

The type locality was originally described as "a moist, densely shaded, rocky ravine of northern exposure" with crested dwarf iris growing profusely in the rich, sandy loam.

*Habits.* We found *ouachitae* chiefly in and under rotting logs, under bark either on the ground or still undetached from decaying logs, and under the forest debris. Stones were not shunned; due to the great number of stones on Rich Mountain they must be considered an important *ouachitae* retreat and, incidentally, one that will prevent its extermination by avid collectors. The single specimen that we took at a low altitude was hiding under a small pine log. We did not collect about streams of any size and therefore could not determine whether *ouachitae* has any special association with them. Burt (1935, p. 312) found his near a spring, and we found ours near spring streams as well as far from them.

*P. ouachitae* seemed to be less agile than *P. g. glutinosus*.

The fourth site described above deserves further description because here, perhaps in part due to disturbed conditions, the species was inordinately abundant: in about two hours we caught 131 specimens in three adjacent niches as follows: (1) Eleven were under well-weathered to rotten boards lying in broken shade and piled approximately 1.5 feet deep on an area measuring 12 by 14 feet. (2) Three were under widely scattered boards of the immediate vicinity. (3) One hundred seventeen were in a pile of partly decayed shingles, 20 feet from the pile of boards and under a tree.

These shingles were piled closely (except at the periphery) to a maximum height of two feet, and covered an area measuring roughly 15 feet in diameter. Since we removed the shingles one by one until compact earth was reached, we probably secured at least 95 per cent of the inhabitants; many were released in the same shingles after we had re-piled them. The original pile evidently made an ideal niche for the salamanders, and probably harbored a saturated population.

On the basis of this big catch it is interesting to speculate on the possibility that the number living in the well-clothed talus slopes of Rich Mountain is much greater than the purely surface collecting indicates; the fragments of sandstone are for the most part hard to move and the alarmed salamanders even harder to catch before they retreat to lower levels.

Largely because of the very late and (for a time) dry spring we secured only one specimen of *ouachitae* and none of *glutinosus* before April 30, although we started looking on the seventeenth. Our lack of familiarity with the area was also a factor. We shall not publish all our daily weather and temperature records since we were unable after the advent of favorable weather

to return for comparative data to most of our early collecting sites. Records made on the few days during which we were successful are of interest in showing positively the temperatures at which *ouachitae* and *glutinosus* are active. The days from April 18 through 27 were rainless except for 0.5 inches that fell on the night of April 18 (our first *ouachitae* was caught on the 19th) and 0.25 inches during the night of the 23rd. The morning (6:00 to 7:30) shade temperatures at Eagleton (1500 feet) were from 40° F. to 50° F. on six of these days and only 55° F. to 65° F. on the others. Table I shows the conditions at Eagleton during the period of our big catches. Little or no collecting for *ouachitae* was done on April 28 and 29 and on May 4.

**Table I. Temperature and Weather at Eagleton April 28 through May 6, 1950.**

Date and catch	Temperature (Fahrenheit)			Rainfall (inches)
	6:00-7:30 A.M.	1:00-3:15 P.M.	3:30-10:30 P.M.	
April 28	57	70	68	1.5 in night
April 29	61	80	70	0.25 in night
April 30 (11)	52	69	57	1 in night
May 1 (18)	59	69	60	1 in night
May 2 (14)	55	79	68	0
May 3 (18)	67	77	74	trace in night
May 4	71	74	73	trace in day
May 5 (3)	63	71	57	trace in night ?
May 6 (131)	59	59	61	rained in afternoon

The poor catch on May 5 was apparently due to the dry conditions, which were augmented by a high wind of the preceding night and afternoon. Again the importance of rainfall to salamander activity is emphasized.

*Parasites.* The original describers (Dunn and Heinze, 1933, p. 122) mention a heavy infestation of mites. In our series 83 per cent of the specimens are infested and many adults have from 10 to 15 sites of infestation (small, red, raised areas). These occur on head, body, and legs, but are most numerous on the sides, the lateral aspect of the back, and the legs, including the feet.

The specimens of *Plethodon glutinosus* taken on Rich Mountain were not infested although they were living in close association with *P. ouachitae*.

### SIZE, GROWTH, AND THE SEXES

*Size at Sexual Maturity.* The cloacal gland papillae and the mental gland of the males give a clue to the size at which sexual maturity is reached.

Cloacal gland papillae. With one possible exception, all males more than 48 mm. in length from snout to vent have these papillae (Fig. 3). This one (57 mm.) appears to be abnormal in cloacal structure. In three others of various sizes (not indicated on the histogram) the papillae are but poorly developed.

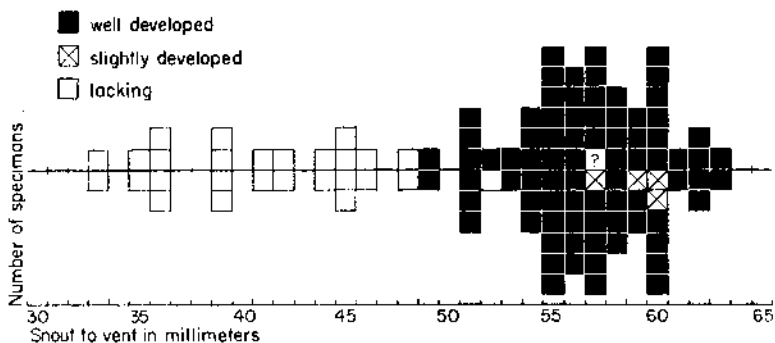


Figure 3. Cloacal gland papillae (above line) and mental gland correlated with snout vent length in 56 male *P. ouachitae*.

Mental gland. This gland is never evident in specimens less than 49 mm. long from snout to vent. It is lacking in one larger specimen (52 mm.) and but slightly developed in four still longer ones. The remaining specimens 49 and more millimeters long can be divided further into two fairly equal groups on the basis of degree of development of the mental gland, but this division, not indicated on the histogram, is scarcely surprising in view of the time of year (spring) that the collection was made.

The appearance of these two male secondary sexual characters at the same stage of growth in *ouachitae* stands in contrast to their appearance at slightly different stages in *glutinosus* (Pope and Pope, 1949, p. 254-255) and *yonablossee* (Pope, 1950, p. 93-94).

Gross examination of the *ouachitae* testis indicates that sexual maturity is reached by males just after they attain a length of 47 mm. This close agreement with the results of the study of the secondary sexual characters is most gratifying.

*Rate of Growth.* When the series of 125 specimens is placed on a histogram (Fig. 4) clearly distinct age groups are not evident. In fact, the usual peak made by the young of the preceding year is conspicuously absent (compare the histogram by Pope and Pope, 1949, p. 259, for *glutinosus*, and by Pope, 1950, p. 94, for *yonahlossee*). In spite of this lack of juveniles, it may be reasonably concluded that the growth rate of *ouachitae* is like that of these other two species, i. e. sexual maturity is attained by the fourth season of life at an age of almost three years.

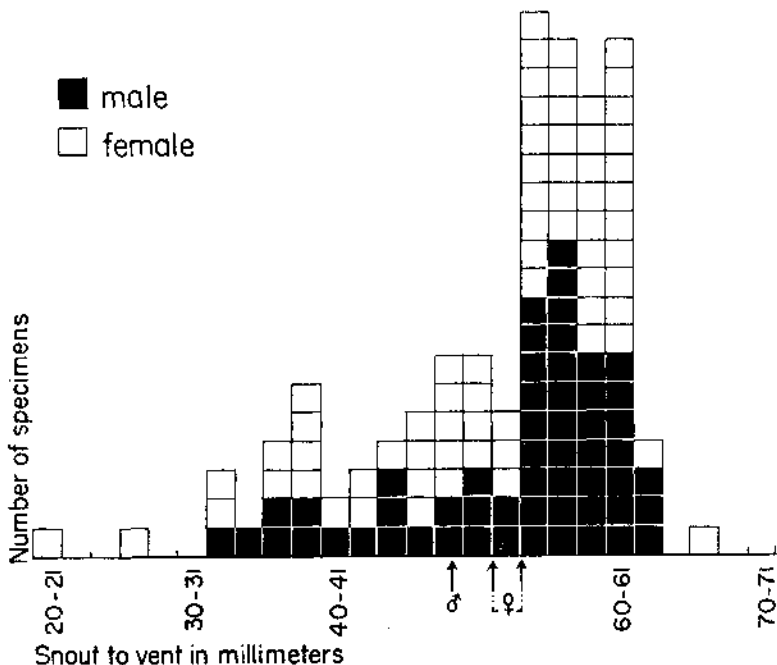


Figure 4. Size (snout-vent) distribution of the 125 specimens of *P. ouachitae*. Arrows indicate size at maturity.

This absence of very young individuals is without ready explanation. If, as explained elsewhere, a large part of the series had not been taken from a shingle pile that seemed to harbor a complete population, it might be concluded that the young were not yet out. Figure 5 shows that in size distribution the structure of the population from the shingle pile is normal because it is similar to the collection made in the undisturbed woods.

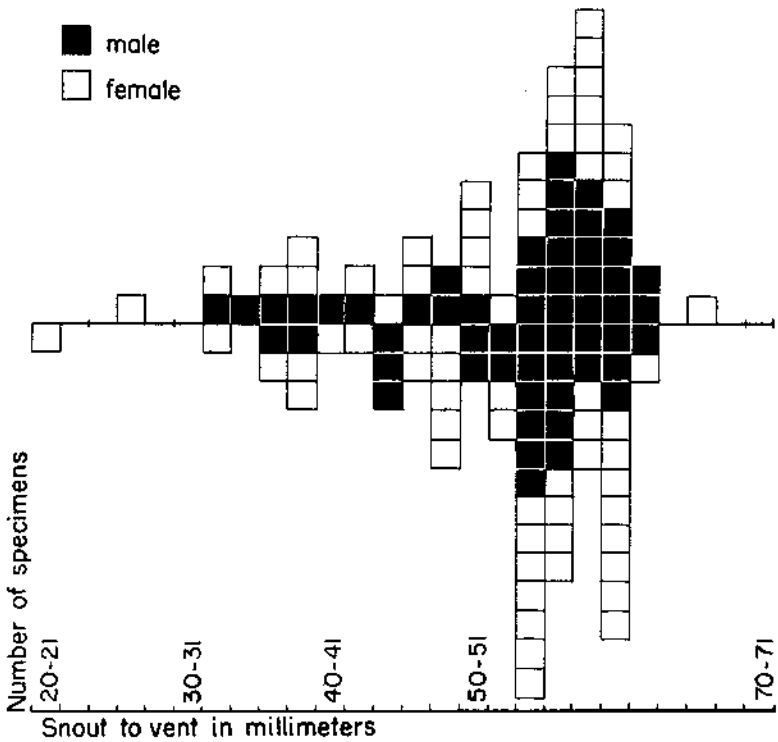


Figure 5. Structure of population of 60 *P. ouachitae* from shingle pile (above line), compared with population of 65 from undisturbed woods.

*Sexual Dimorphism in Length.* Sexual dimorphism in length, although slight, is statistically significant as shown by Table II, which is based on the mature males and females. The maximum total length for males and females,

Table II. Snout-vent Length of Mature *P. ouachitae*.

Sex	Number	Extremes	Mean
Male	43	49-63	56.7 $\pm$ 0.49
Female	35	54-67	58.5 $\pm$ 0.45

respectively, is **137** and **140** mm. The tail of the female may even be incomplete. One of the paratypes is slightly longer (**71** mm. snout-vent, Dunn and Heinze, 1933, p. 122) than any specimen preserved by us. Taking **2** mm. off to compensate for the probable difference due to measurement to the pos-

terior tip of the vent, this individual, a female, still is longer by 2 mm. than any in our series. The total length of 91 mm. indicates that much of the tail of this paratype is missing.

*Sexual Dimorphism in Shape of Snout.* The male has a pronounced swelling of the upper lip below each naris, whereas the female has a similar but much less noticeable one.

*Relative Number of the Sexes.* The series of 125 specimens is made up of 56 males and 69 females. However, only 12 or 13 of the males are immature as against approximately half of the females. The series of 60 from the fire lookout site is equally divided between the sexes.

### REPRODUCTION

*Breeding Season.* As in the case of *yonablossee*, examination of the ovaries and oviducts reveals a lack of uniformity in condition that makes difficult the drawing of a conclusion about the laying season. Among 35 adult females six have large ova and greatly swollen and convoluted oviducts, 13 much smaller ova, and oviducts that are not swollen and convoluted. The remaining 16 are more or less intermediate, although not as uniform in condition as are the extreme groups. We judge from these data that the laying season is an extended one.

On May 24, 1950, Dr. James Kezer kindly made smears of the testes of three adult males that we secured at the fire lookout site on May 6, and brought to Chicago alive. A testis of one of these was in an immature condition, attenuated and without a swollen, pale posterior part; a testis of another was but little swollen and slightly pale posteriorly; these two contained nothing but spermatogonia. A testis of the third was club shaped, the enlarged posterior part containing what appeared to be spermatocytes in very early prophase of the first meiotic division. Thus it is evident that during the spring the *onachitae* testes, in contrast to those of *yonablossee* and *glutinosus* (Pope and Pope, 1949, p. 254; Pope, 1950, p. 96), are as yet quiescent. Mating certainly does not take place at this time of the year.

It is interesting to note that the adult females, 14 in number, from the exposed site on the very top of the mountain (2825 feet altitude), are definitely more retarded in development than are those from the lower (1950 to 2150 feet, except one from 1700 feet) sites in the woods on the side: none of the six with the largest ova is from the top, whereas nine of the 13 with the smallest ova are.

*Fecundity.* Some indication of the number of eggs laid at a time may be gained from the counts of the advanced ova in the 22 females that have them. The average number is  $16.7 \pm 0.95$ , the extremes 13 and 23. The

largest female had the highest count; 19 large ova were found in five, whereas 20, the second highest number, were counted in two.

#### VARIATION

*Variation in Color.* The variation in coloration exhibited by a series of living individuals of *P. ouachitae* is astonishing and far exceeds that of any allied form. This remarkable condition has never been described. Dunn and Heinze (1933, p. 122) state that this species in coloration is more like *yonahlossee* than it is like *wehrlei* but, as shown below, only an occasional individual looks like *yonahlossee*. The dorsal white speckling of some suggests *glutinosus*; this resemblance is superficial.

We have detected no sexual dimorphism in color.

The following descriptions, except as otherwise stated, are based on field notes made at the time of (formalin) preservation of the series of 125 individuals, and therefore represent the colors in life.

Back. Three color elements occurred independently of one another and in varying amounts on the black ground color of the back: a shiny, silvery pigment described below as "frosting"; red pigment; white speckling. Each element will be analyzed separately.

The frosting almost covered the back, occurred as irregularly shaped areas of different sizes, or was entirely lacking. We divided the series into four groups in respect to this character with the following results: dense, 9 per cent; moderate amount, 28 per cent; a little, 44 per cent; lacking, 19 per cent. After having been in alcohol about five months, the specimens cannot be divided into these same groups because the silvery pigment, though still more or less evident (but no longer silvery), is not readily distinguished from other color elements.

The white speckling, the largest specks of which might be described as small spots, was profuse in 18 per cent, moderately so in 19 per cent, sparse in 38 per cent, sparse except on the base of the tail in 23 per cent, and lacking in 2 per cent. This speckling is much less changed by preservation than is the frosting.

A red pigment overlay the black ground color of all or nearly all of the back in 15 per cent of the specimens, whereas in 21 per cent the back was nearly all black. In 64 per cent an intermediate condition was noted. The red is normally very dark but 7 per cent of the specimens exhibited a definitely lighter shade. This red pigment is not evident in the specimens preserved about five months.

Top of head. The top of the head was like the back in 30 per cent of the specimens, whereas in 70 per cent the red element was less evident than on the back.

Sides. White pigment was evident on the sides from the level of the limb insertions to the belly, which it often encroached upon. In 85 per cent of the specimens it formed a continuous band; in 15 per cent the band was diffuse, e. more or less broken up into discrete spots or patches. This pigment persists after about five months of preservation.

Belly. The belly was black, or black with a highly variable amount of light pigmentation in the form of faintly yellowish specks, spots, or small areas of irregular shape, all mixed helter skelter together. The light pigment was most evident anteriorly, especially between the forelimbs; it was least in evidence near the midline of the belly. The following enumeration describes the distribution of the yellowish pigment.

Profuse, especially anteriorly	15 per cent
Profuse only between front legs, almost absent elsewhere	6 per cent
A little between front legs and a trace elsewhere usually along sides of belly	18 per cent
A trace between front legs, none elsewhere	19 per cent
Absent, or present only as a few widely scattered specks	42 per cent

This pigment persists well in the specimens that have been preserved about five months.

Throat. When a series was viewed *en masse* the lower side of the head appeared to be light, but scrutiny made it evident that, in most individuals, there was at least some suffusion of grayish pigment. This was profuse in 28 per cent (almost solid black in one individual), moderately evident in 45 per cent, and little evident or lacking in 27 per cent. Considering this character alone, only the single black-throated specimen might have been confused with the half-grown or adult Rich Mountain *glutinosus* that we collected. This throat pigmentation persists in preserved specimens. Some light yellow mottling was evident on the sides of the throat in 93 per cent of the specimens, but absent in 7 per cent. Although still evident, this mottling has argely lost its yellow hue after about five months of preservation.

Legs. Numerous white spots and areas of various sizes are present on the legs in the material preserved about five months. They are very profuse n some 30 per cent, moderately so in about 57 per cent. The remaining 13 per cent of the specimens average only a few small spots per leg. This rating is highly subjective since it is hard to decide in which category many individuals should be placed. Notes made on a small series in the field compared with data from examination after preservation indicate that a few of these

light areas almost disappear in preservative, whereas most of them remain clearly evident.

There appears to be a correlation between the amount of light pigment on the ventral side of the front legs and on the belly: the specimens with profuse (light) pigmentation on the chest also have much on the lower aspect of the front legs. However, many with little to none on the chest have a moderate amount on the lower side of the legs. This means that the lower aspect of the hind legs has less light pigmentation than does that of the front legs since, as explained above, the (light) pigmentation is much the more profuse anteriorly on the belly.

Juveniles. The juveniles have been included in the foregoing color descriptions because in life no difference was noted between them and the adults. After about five months of preservation, the next to the smallest individual, a female measuring 26 mm. from snout to vent, shows two rows of very faintly pink spots down the back, three to five spots in each row. These are just possibly comparable to the red juvenile spots of allied forms. In life this individual was described as having a moderate amount of frosting, which no doubt largely obscured the small amount of dark red pigment that was seen on the back. The persistence of a trace of the red pigment is taken as evidence, slim though it be, that this individual differs from the rest of the series, which has lost all trace of red pigment.

The belly is well pigmented in all but the smallest individual (20 mm. snout-vent). In this one the melanophores have not yet covered an area extending along the midline of the belly, perhaps a quarter of the belly being without dark pigmentation.

*Vomerine Teeth Counts Correlated with Snout-vent Length.* Counts of the vomerine teeth were made on all but the smallest specimen of the entire series of 125 as shown graphically in Figure 6. The lowest count on one side is four and only the smallest individual (20 mm. snout-vent) of the 125 counted has it. The specimen next in size (26 mm.) has five teeth on each side. The higher counts are relatively uniform; the highest, 18, is found in a 59-mm. female, the next, 15, in a 58-mm. specimen of the same sex.

Taking the sum of the two sides as a unit, the mean count for the 43 adult males (49 to 63 mm.) is  $21.6 \pm 0.40$ ; for the 35 adult females (54 to 67 mm.) it is  $22.2 \pm 0.46$ . In number of vomerine teeth adult *ouachitae* agrees closely with adult *glutinosus* (Pope and Pope, 1949, p. 260).

The original description (Dunn and Heinze, 1933, p. 121) gives the number of vomerine teeth as 7 to 9 on a side; Bishop (1943, p. 271) raises the upper limit to 13.

*Variation in Costal Groove Counts.* We have devised a scheme that divides the grooves themselves into three types: full length; slightly shortened (at least two-thirds full length); greatly shortened, elongate depressions to mere dents. The shortest one is always the most posterior of the series, and all the shortened ones arise on a line with the dorsal tips of the fully developed ones, i. e. they are abbreviated from below, so to speak.

In the following tabulation the number of full to almost full length grooves is separated by a plus sign (+) from the number of depressions or dents, and an S before a number indicates that the terminal groove of the series is a slightly shortened one. Thus, S14 + 1 means that, counted from the front leg, there are 14 grooves with the last one or fourteenth slightly shortened, *and* an ultimate dent or elongate, groove-like depression.

14-groove group: 8 specimens

13+1 and 13+1 in 7

13+1 and S13+1 in 1

14- and 15-groove group: 4 specimens (asymmetrical)

13+1 and 13+2 in 2

13+1 and S14+1 in 2

15-groove group: 59 specimens

13+2 and 13+2 in 28

S14+1 and S14+1 in 18

13+2 and S14+1 in 7

13+2 and 14+1 in 3

S14+1 and 14+1 in 3

15 and 16 grooves: 1 specimen (asymmetrical)

14+1 and S14+2

16-groove group: 4 specimens

14+2 and 14+2 in 2

S14+2 and S14+2 in 1

S15+1 and S15+1 in 1

To make the above counts comparable to Bishop's ("15-17, the usual count being 16 when 1 each is counted in the axilla and groin," 1943, p. 271), one (axillary) groove must be added arbitrarily to each of my counts, making 16 the usual number (59 out of 76). In the original description (Dunn and Heinze, 1933, p. 122), six among eight are listed as having 16 grooves, one as having 15, and one 17.

This method may unduly complicate the counting of costal grooves, but at least it shows the great variation of groove structure in *Plethodon ouachitae*, and focuses attention on methods of dealing with this notoriously misleading character. Interspecific variation cannot be understood until ways of indicating intraspecific variation have been worked out. As previously ex-

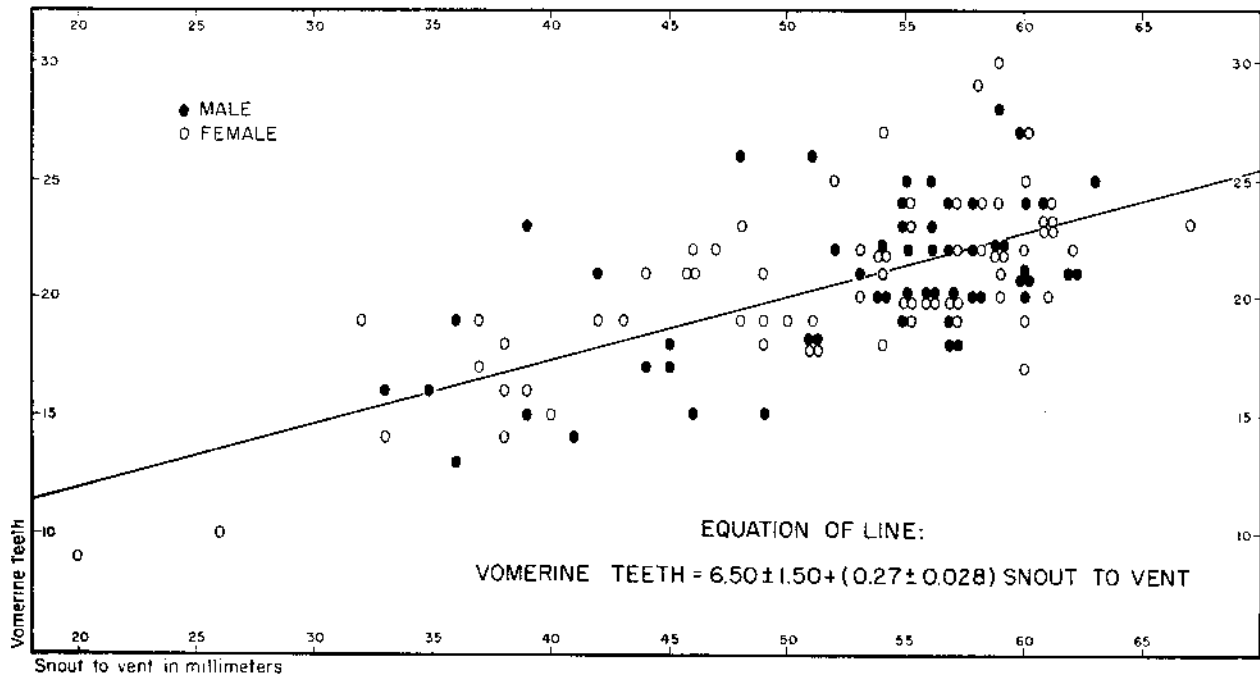


Figure 6. Number of vomerine teeth plotted against snout-vent length in 125 specimens of *P. ouachitae*.

plained (Pope, 1950, p. 102), the complex shape of the inguinal groove (or grooves), and groove-like structure (or structures) makes it imperative that the same worker count all individuals, or that the method used allows different workers to attain comparable results.

*Variation in Relative Tail Length.* Table III, based on all specimens with complete tails of the series of 125, shows the length of the tail expressed in percentage of the snout-vent length of all the mature specimens and of the smaller immature individuals, which actually include all the immature males.

**Table III. Tail Length Correlated with Length from Snout to Vent.**

	Number of specimens and snout-vent range (millimeters)	Tail/snout-vent length (%)	
		Extremes	Mean
Mature males	19 (49-63)	102-128	117 $\pm$ 0.61
Mature females	15 (54-61)	105-132	120 $\pm$ 0.68
Immature ♂ and ♀	15 (20-48)	90-128	115 $\pm$ 0.34

Some of the smaller ones have body and tail about equal in length, a condition occasionally found in adults. It is probable that body and tail are equal at first; this cannot be proved until more very small specimens are available.

The body-tail ratio of the adults is surprisingly similar in *ouachitae*, *glutinosus* (Pope and Pope, 1949, p. 258) and *yonablossee* (Pope, 1950, p. 102).

#### Description of a New Form Allied to *Plethodon ouachitae*

##### *Plethodon caddoensis*, new species

*Diagnosis.* The habitus is like that of *P. ouachitae* but the coloration differs noticeably: frosting lacking on back (present in 81 per cent of *ouachitae*); white speckling lacking on back (present in 98 per cent of *ouachitae*); red pigment lacking on back (79 per cent of *ouachitae* had more than a trace); side with a diffuse band of white pigment (a continuous band in 85 per cent of *ouachitae*).

*Type.* Chicago Natural History Museum 61959, from an altitude of 1200 feet on Polk Creek Mountain of the Caddo Mountains, southwestern Montgomery County, Arkansas (Fig. 1). Collected May 9, 1950, by Sarah H. Pope.

*Paratypes.* A female from the type locality (CNHM 61960) collected May 9, 1950, by Clifford H. Pope at 1200 feet, and a female (CNHM 61958) from Caddo Gap of the Caddo Mountains of Montgomery County (Fig. 1), collected on May 8, 1950, by Clifford H. Pope, at 950 feet. A third speci-

men (MZUM 82791) is from Caddo Gap but, after 15 years of poor preservation, its color characters have largely disappeared and identification has become difficult.

*Range.* Known with certainty only from the Caddo Mountains of Montgomery County, Arkansas, 950 to 1200 feet altitude. Possibly from the vicinity of Mt. Ida, Montgomery County. Mt. Ida itself is only 700 feet above sea level but several mountains nearby reach an altitude of 1000 feet or a little more.

*Description of type.* An immature female 104 mm. in total length, 45 mm. from snout to anterior angle of vent; costal grooves 14+1 on both sides (see above discussion of grooves in *onachitae*); vomerine teeth 12 on each side.

Ground color of body black above and below, extremity of tail lighter; back and upper sides with profuse, pale, white spotting that stands out less than do *glutinosus* spots and *onachitae* speckling; lower sides with white spots forming a diffuse band as in some specimens of *onachitae*; top of head like back but with light spotting that becomes less distinct and smaller on snout; belly with profuse light areas (like those of *onachitae*) between arms, and a few scattered over belly; throat light with trace of dark mottling laterally; sides of head with yellowish mottling posteriorly; legs black with light spots above and below, these spots slightly more numerous on front legs; proximal two-thirds of top of tail with white speckling like that usually evident on the back of *onachitae*.

The foregoing and following color descriptions were made at the time of preservation.

*Variation.* The two paratypes collected by us are strikingly like the type except in minor details. Both are immature females one, 61960, measuring only 81 mm. in total length (36 mm. snout to vent), the other 47 mm. in snout-vent measurement (tail incomplete). The vomerine teeth are 10-11 in the larger, 10-9 in the smaller. In both, the white spots of the back were separated by a narrow line of ground color, a condition never seen in *onachitae*. The dark mottling of the throat is very pronounced in 61958.

The similarity of these and the fact that the three were taken at two places several miles apart make it highly improbable that they are merely aberrant examples of *onachitae*. It should not be forgotten that we secured them only a few days after collecting and closely examining a large series of *onachitae*.

The relationship between this new form and *onachitae* may well be sub-specific; final word will have to await study of more material of *caddoensis*. The geological history of the region already outlined is of importance in this connection.

*Habitat.* The type and smaller paratype (61960) were taken 0.3 miles north of the pass (altitude of pass: about 1250 feet) between Polk Creek Mountain (1750 feet) and the southeastern spur of Statehouse Mountain (altitude of Statehouse Mountain: 2127 feet) and just west of the road that crosses the pass. They were found in mixed-deciduous, second-growth woods with some pine growing in a wide, shallow valley with moderate ground cover on a stony substratum. The type was hiding under a very small log in a grove with thin ground cover and small trees, an unlikely spot compared with the better woods nearby where 61960 was discovered. Number 61960 was under a 3-foot section of a log about a foot in diameter lying in heavier, leafy ground cover. The paratype (61958) collected at Caddo Gap was in an unlikely place well up (950 feet) on the western face of the gap and above the thick woods of the lower part of the face. The specimen was hiding under a small log in a thin, scrubby, mixed-deciduous and pine growth on the steep slope. There was much thick grass on the relatively dry, sparsely covered ground, much of which was exposed to direct sunlight.

Until more is known about these Plethodons we dare not assert that their habitat preferences differ but the indications are that *caddoensis* has greater tolerance of dry conditions. The fact that in four hours of collecting we could find only three specimens may prove nothing because the dry weather conditions were highly unfavorable and most of the woods in which we worked do not hold moisture long. No other large Plethodons were seen, although a few *P. cinereus serratus* were found in the lower, heavier woods on the western face of Caddo Gap, and one at the type locality on Polk Creek Mountain.

The specimen discussed above (CNHM 2096) as probably from the vicinity of Mt. Ida, which is within the Novaculite Uplift, would be expected to belong to the new form. However, examination of it reveals that, although the ventral aspect is like that of *caddoensis*, the back and sides differ noticeably in lacking light pigment. Its good condition indicates that this difference is real rather than the result of 13 years of preservation; specimens of *onachitae* (CNHM) collected in 1938 still have the lateral pigment. We shall suppress the temptation to describe it as a new form, and consider it as a highly questionable record of *caddoensis*. Since *onachitae* is such a variable species, the new form, being closely allied, might well be variable too; one would not be surprised to find this variability expressing itself in still further reduction of pigment.

Number 2096 measures 47 mm. from snout to vent, has 14-14 vomerine teeth, and 14 +1 costal grooves on each side.

## SUMMARY

Field studies of *Plethodon ouachitae* of eastern Oklahoma and western Arkansas were made, and a statistical study of its growth and reproduction was based on a series of 125 preserved specimens.

The known range of the species is shown to be Rich Mountain, where it is abundant; its vertical distribution was found to be extensive. A new and closely allied form is described from the nearby Caddo Mountains and, possibly, from the vicinity of Mt. Ida. The influence that the geological history of the region has had on the distribution of these salamanders is considered.

*P. ouachitae* is closely associated with *Plethodon glutinosus glutinosus*, at least on the sides of Rich Mountain, where the former is about five times as abundant as the latter.

*P. ouachitae* is a woodland salamander that frequents various niches of the forest floor. The numerous, heavily overgrown talus slides of Jackfork sandstone constitute a favored and extensive niche.

This species was found to be especially abundant in a pile of shingles on the very top of Rich Mountain. This site is described in detail and its population analyzed.

Secondary sexual characters of *ouachitae* indicate that males reach maturity when they measure 48 mm. from snout to vent. Examination of the testes provided confirmatory evidence. Both sexes probably attain maturity by the fourth season of life at an age of almost three years. Females slightly exceed males in adult size, the snout-vent averages being 58.5 and 56.7.

Females noticeably outnumbered males in the whole series of 125 specimens, a difference that was due to the relatively greater number of immature females; the ratio between mature and immature individuals was about 1 to 1 among the females, 3.5 to 1 among the males.

Examination of ovaries and oviducts failed to give conclusive evidence of the extent of the breeding season but suggested an extensive one. Examination of the testes indicated that mating does not take place in the spring.

The average number of advanced ova in 22 females was 16.7; the extremes were 13 and 23.

A detailed analysis of variation in coloration was made for the most part just before or just after preservation, and the remarkable variability of *ouachitae* pointed out. Variation in the number of vomerine teeth, costal grooves, and relative tail length was also studied.

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